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BEAM TEST RESULTS OF THE BTEV SILICON PIXEL DETECTOR

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We report the results of the BTeV silicon pixel detector tests carried out in the MTest beam at Fermilab in 1999-2000. The pixel detector spatial resolution has been studied as a function of track inclination, sensor bias, and readout threshold.

1 Introduction

BTeV has beam-tested single-chip silicon pixel detector prototypes and front-end readout chips in developing its vertex detector[2]. Of particular interest was a comparison of the resolution obtained, using 8 bit and 2 bit charge information, for a variety of incident beam angles (from 0 to 30 degrees). Spatial resolution was studied as a function of sensor bias and readout threshold. Here, only a very brief summary of the major results is presented. A more detailed discussion can be found in Ref. 3.

2 Experimental Setup

The tests were performed with a Fermilab 227 GeV/c pion beam incident on a 6 plane silicon microstrip telescope. The pixel sensors have 50 μm $\times$ 400 μm pixel size and are all from the "first ATLAS prototype submission" (both p-stop and p-spray types).[4] Up to four pixel detectors could be tested simultaneously.

Two types of readout chips were used, called FPIX0 and FPIX1.[5] Each FPIX0 readout pixel contains an amplifier, a comparator, and a peak sensing circuit. The analog output is digitized by an external 8-bit flash ADC. FPIX1 is the first implementation of a high speed readout architecture designed for BTeV. Each FPIX1 cell contains an amplifier, very similar to the FPIX0 amplifier, and four comparators, which form an internal 2-bit flash ADC. Each readout chip was indium bump-bonded to its sensor. The pixel detectors were calibrated using a pulser and two x-ray sources (Tb and Ag foils excited by an ^{241}Am α-emitter).

The readout threshold for FPIX0 was typically 2200-2500 equivalent e^- at the front end. The FPIX1 threshold was typically 3800 e^-. The FPIX0 and FPIX1 amplifier noise levels were typically 80 to 185 and 110 e^-, respectively. The relatively high FPIX1 readout threshold was due to noise and pickup problems in a circuit-board interface.

The extrapolation accuracy of the silicon microstrip telescope at the pixel detectors location was ~ 2.1 μm. In order to select tracks incident on the active area of the pixel detectors, the FAST_OR output signal from one of the FPIX0-instrumented pixel detectors was required in the on-line trigger.

3 Results

The coordinate measured by a pixel detector is obtained by the position of the center of the cluster of hit pixels associated with a track, plus a linear "head-tail" correction which uses only the charge deposited on the edges of the cluster[8]. "Digital" positions are calculated without head-tail correction. By 10 degrees from normal incidence, there is always charge sharing across adjacent pixels. Resolution is somewhat degraded by charge loss near pixel boundaries as seen by ATLAS,[6] but these regions are included in all results.

The residual distribution widths, obtained for several track angles and various detectors, are shown in Fig. 1. The exper-

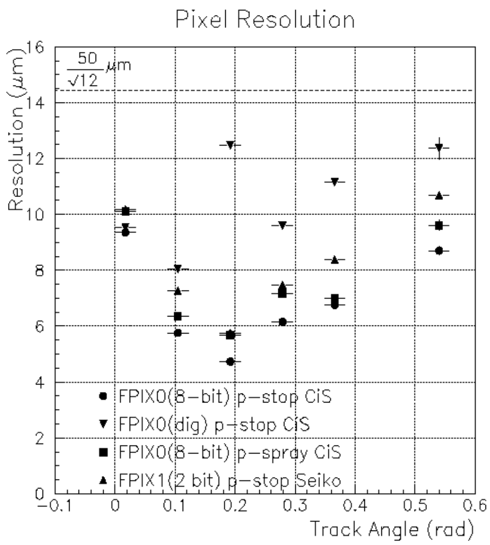

Figure 1. Position resolution along the short pixel dimension as a function of beam incidence angle for several detectors.

imental results are in good agreement with the simulation results described in Ref. 9. Due to diffusion, even the digital-position-calculation resolution is better than the pixel pitch divided by $\sqrt{12}$. The resolution of the FPIX1-instrumented p-stop detector is slightly worse than the results that we obtained by degrading by software the FPIX0-instrumented p-stop pulse height information to 2-bit equivalents. This is because the main effect degrading the resolution is the high threshold, with the 2-bit analog information only a minor effect. Comparing the p-spray and p-stop detectors in Fig. 1 (thresholds of $\sim$2200 e^-) show the charge losses in the p-spray sensor degrading the spatial resolution by a half to one micron.

For large track angles, there is not too much sensitivity to the bias voltage because the charge-sharing is dominated by the track inclination. At normal beam incidence, when the diffusion gives a substantial contribution to the charge-sharing, the sensor bias is important. The spatial resolution is still better than $10\mu m$ up to a threshold of $3800e^-$ (FPIX1 in Fig. 1). It does deteriorate rapidly for thresholds above $4000e^-$.

4 Summary

The spatial resolution achieved with FPIX0 and FPIX1 readout of ATLAS sensor prototypes is $< 10\mu m$ for a large range of incident track inclination, even using only 2-bit charge information. The resolution has a relatively small dependence on bias voltage, but does depend significantly on the discriminator threshold.

References

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